



0 293 021
A2

12

EUROPEAN PATENT APPLICATION

②¹ Application number: 88200614.1

⑤¹ Int. Cl.⁴: C30B 25/10

② Date of filing: 31.03.88

The title of the invention has been amended (Guidelines for Examination in the EPO, A-III, 7.3).

③ Priority: 24.04.87 IT 2025587

④3 Date of publication of application:
30.11.88 Bulletin 88/48

⑧ Designated Contracting States:
CH DE FR GB LI NL

71) Applicant: LPE SPA
Via Stella Rosa (Head Office)
I-20021 Ospiate di Bollate Milano(IT)

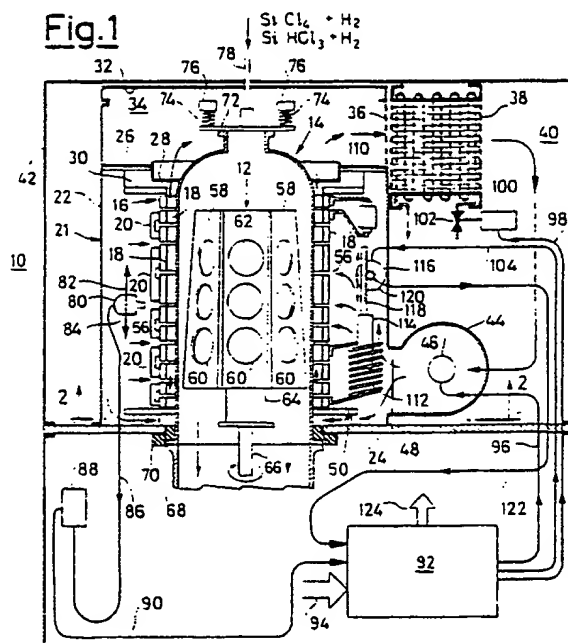
(72) Inventor: **Pozzetti, Vittorio**
Via Volturmo 80
Brugherio (Milano)(IT)
Inventor: **Preti, Franco**
Via S. Benigno 4
Milano(IT)

Inventor: Poggi, Piergiovanni
Via delle Scuole 24
Lugano Cassarate(CH)

74) **Representative: Michelotti, Giuliano et al**
c/o SAIC BREVETTI S.r.l. Viale Bianca Maria
15
I-20122 Milano(IT)

⑤⁴ Induction heating system for an epitaxial reactor.

57 Is described a reactor for chemical vapor deposition of epitaxial layers on crystal substrates, using a medium frequency induction heating system, the power for said heating being provided by a multi-turn coil (16), inducing electrical currents in a susceptor (12) of electrically conductive material, as graphite, said heating being controllable through fine local and readily automaticable current regulators in single turns (18) of said coil (16) and through properly shaping the walls (59) of said susceptor (12) in order to control temperature gradients therein.



"Improvements in epitaxial reactors"

The present invention regards improvements to inductors and susceptors usable in epitaxial reactors to increase their yield, reduce parasitic heat production and minimize the temperature gradients in said reactors and specifically in the articles treated therein.

In the semi-conductor industries it is well known the use of epitaxial reactors providing to cover substrate of different materials through epitaxial growth by chemical vapour phase deposition: specifically said reactors are used to provide epitaxial deposition of monocrystal silicon on silicon substrate for the manufacturing of semi-conductor devices. Among the many epitaxial reactors which historically became popular in the semiconductor industry, distinguishes itself by the excellent features that specified and claimed in the US Patent No. 4,579,080, having as authors John. G. Martin et al. to which references is made, using a susceptor having a multi-face prismatic or truncated pyramidal shape, enclosed in an insulating bell jar non reactive in respect of the chemical vapors inside said bell jar, being said bell jar covered by a reflective layer, as a metallic layer, to reflect the heat irradiated by said susceptor during its working, in order to reduce the power consumption and to uniform the temperature of said susceptor, and surrounded by a cooling liner cooled by a liquid, such as water, to held the walls of said bell jar to such a temperature to prevent a substantial deposition on said walls of matter potentially contaminating in the substrates treated in the reactor.

Said bell jar is surrounded by an inductor or coil energized by medium-frequency alternating current (between 1 and 15 kHz) to provide power to heat said susceptor, formed by a conductor wound in many turns properly spaced by provide to said susceptor a power variable from a point to another, as particularly specified at column 12, lines 59, 67 of the above mentioned patent.

If owing to some reason the local power in the susceptor must be changed, the spacing between adjacent turns must be variated through means controlling said turn spacing, which have some mechanical and spacing range problems connected with the dimensions of said conductors. Moreover, where the turn must be held more spaced, the conductors forming the coil do lie on planes no more perpendicular in respect of the susceptor axis and, as a consequence, being the electrical current therein induced parallel to said turns, give a local heating producing the same substantial thermal gradient, which further, owing to the susceptor rotation, produces a time variation or pulsation of the local heating enhancing those thermal gradients,

sought to be reduced, with the consequent production of crystal defects or flaws in the substrates or wafers to be treated.

Further the susceptor, formed by a good electrical conductor, such as graphite, possibly covered by a material, such as silicon carbide, well resistant in respect of the chemical reactives and gaseous by product present in the reactor is provided with the thickenings or projections in some regions, such as regions around pockets or indentations housing the substrates or wafer to be heated (see column 8 lines 50-55) and with thinnings at some other regions as the dihedral corners and upper and lower regions (see column 13 line 66 to column 14 line 14) having the purpose to distribute the heat according to desired patterns.

However such patterns required a tedious and time consuming empirical process to find out the best shape giving the best thermal results, producing more uniform temperature profiles across the faces of the sidewalls of the susceptor.

Lastly, it is asserted in said patent that, owing to the heat irradiated by the susceptor and to the heat produced by induced currents within the reflecting metallic layer lining the quartz bell jar, it is very difficult to obtain an efficient cooling by blowing air, and, as a consequence, it is preferred to use water cooling provided by a water travelled liner surrounding said bell jar (see column 11, line 57 to column 12, line 17).

The present invention intends to find out a remedy for the above listed problems, using a quartz bell jar without any reflecting layer and liquid cooling liner and charging for said reflecting function the internal regions of the conductors making up said inductor or coil, which are manufactured with proper reflecting features.

This system, not having any more a reflecting layer on the bell jar walls reduces the bell jar heating avoiding any induced current in said reflecting layer, and moreover, as the conductors of the coil are hollow and travelled by a cooling liquid, they cool so efficiently said reflector, that it is possible to use an efficient cooling of the bell jar through blowing air.

Preferably, to make particularly efficient said blowing air cooling, a system is provided comprising a fare or blower, compressing air within a chamber completely surrounding said inductor or coil, which air is then discharged through a directing blade assembly or nozzle forming a swirling stream rising from the basis to the top of said quartz bell jar, remaining conveyed between said bell jar and the surrounding coil and then coming out in an upper chamber connected through air-

water heat exchanger, similar to a car radiator, with the blower input.

More preferably, the air, further to contact the bell jar walls at the basis, comes in also through proper gaps, due to the spacing between single turns of the coil adding to the air flow, travelling around the bell jar, some other air further cooling by passing around the coil conductors, which are hollow and liquid cooled.

However, this system, having specifically the great advantage of using a coil formed by ring shaped conducting turns lying on planes substantially perpendicular to the susceptor axis inducing in said susceptor electrical currents perpendicular to said axis in order to avoid the above mentioned pulsating heating connected with the susceptor rotation, has the serious problem of requiring an inductor, with rather closed turns, in order to reduce the solutions of continuity in the reflector around in the bell jar, and fixed shape, so that it is not possible to move turns in order to change locally the electromagnetic field and the power induced in the susceptor.

However, it has been found that it is possible to change locally the magnetic field by changing locally the electrical current in any individual turn of the coil through proper taps connected to non dissipating or reactive controllable circuits which can be inductive, capacitive or both in the nature according to specific needs.

Specifically, if it is desired to reduce the current through some turns, an inductive circuit is shunt connected to said turns, while if it is desired to increase said current, a capacitive circuit is shunt connected. Preferably, the inductive circuit can be made variable either connecting or disconnecting some of its turns, or introducing therein and extracting therefrom a ferromagnetic core of the kind suitable for the working frequencies.

The capacitive circuit can be made variable by using many capacitors shunt connectable through connecting plugs, or hand or electrically controllable switches.

A circuit can be provided by a combination of many inductors and capacitors parallel or series connected among them.

Specifically, it is possible to have a variable circuit having both inductive and capacitive features, by combining together a continuously variable inductor with selectively connected discrete capacitors, the inductor and capacitor assembly so formed permitting a family of current withdrawn and admitting features out and into the turns of the coil heating the susceptor.

According to an alternative solution, the coil reflector assembly is formed by a series of sheet cylindrical surfaces, cut along a generatrix line, anyone of them being surrounded by at least a

hollow liquid cooled conductor welded or soldered against it, the height of said surfaces changing according to the spaces between adjacent turns of the coil and being the conductors series connected between them through bridges permitting the formation of a coil from adjacent turns, lying on planes perpendicular in respect of the axis of said susceptor and serially connected.

According to a preferred embodiment, in order to limit the magnetic field dispersion outside the coil, angularly shaped blocks are provided surrounding the top and the lower edges of said coil and comprising a ferromagnetic material chosen according to the field provided by the coil and the frequency of energizing current thereof.

According to a preferred embodiment, the angularly shaped ferromagnetic blocks are connected by cylindrical shells surrounding said coil.

According to another preferred embodiment, the angularly shaped ferromagnetic blocks are connected each other by columns of ferromagnetic material each other separated and surrounding only partially said coil. According to a last preferred embodiment of the present invention the susceptor has at its lateral corners, bevellings larger outside then inside to keep constant or reduce its thickness in these regions and further some thickness reductions in the walls under the pockets housing the wafers to be treated.

Specifically, these reductions can have the shape of a circular, planar bottom depression, of a circular bevelled bottom depression, or of a generally conical relief from the center to the periphery of said pockets. Further, as the pyramidal shape of the susceptor, embracing a magnetic flux, decreasing from the basis to the top, produces a reduction in the induced power, said reduction can be compensated reducing proportionally the whole thickness of the susceptor in order to maintain a constant current density therein.

The features and the advantages of the present invention, together with other objects thereof, will be clear from the following detailed description of an embodiment thereof, given for exemplificative and non limiting purposes, providing with the enclosed drawings, in which:

- fig. 1 is a diagrammatical sectional view of the epitaxial reactor provided with an improvements according to the present invention;

- fig. 2 is a view, taken along the line 2-2 of figure 1 specifically depicting an air swirling blowing and distributing system according to the present invention;

figure 3, depicts in the sections a) to d) different kinds of reactive circuits differently regulable to control the current in the individual turns of the coil;

figure 4 depicts the impedance and phase features of a reactive circuit according to fig. 3c;

figure 5 depicts the current absorbed from or provided to a coil by a reactive circuit according to figure 3c, in accordance with various inductance and capacity values;

figure 6 is an axial sectional view of a coil and susceptor assembly provided at the ends with angularly shaped blocks of ferromagnetic material to reduce the electromagnetic field dispersion outside the coil;

figure 7 is a view along line 7-7 of figure 6;

figure 8 is an axial sectional view of the coil and susceptor assembly provided with a whole ferromagnetic shell to reduce at most the dispersion of electromagnetic fields;

figure 9 is a view along line 9-9 of figure 8;

figure 10 is formed by back, lateral in cross-section and front views, respectively of a part of susceptor back provided with a depression having shape of a circular planar trench;

figure 11 is formed by back, lateral in cross-section and front views, respectively, of a part of susceptor back provided with depression having shape of a circular trench outside bevelled;

figure 12 is formed by back, lateral in cross-section and front views, respectively of a part of susceptor provided with a generally conical relief outwardly increasing.

Referring to fig. 1, it is seen that an epitaxial reactor 10, according to the present invention, is formed by a susceptor 12 rotatable and introduci-
ble in an insulated and possibly transparent bell jar 14, usually a quartz bell jar. Said bell jar 14 is surrounded by a coil 16 formed by many turns 18 shaped as planar rings, open on a side and connected each other by conducting bridges or jumpers 20, providing the electrical connection between adjacent turns. The turns are essentially formed by a hollow conductor, such as rectangular pipe, travelled by a cooling liquid, such as water, to be maintained to work temperatures, consistent with the proper reactor working. Specifically, it is to note that the hollow conductors, formed by the turns 18 of the coil 16 have different heights according to their position in the coil, being lower at the ends of the coil 16 and higher in an intermediate region thereof in order to permit higher current densities and thus higher heating power, in the end regions of the susceptor 12 and lower densities in the intermediate regions thereof.

The inductor 16 and bell jar 14 assembly is enclosed in a pressurizing chamber 21 formed by a cylindrical wall 22 abutting on a lower plane 24 and top closed by a dividing plane 26, provided with a structure 28 centering said bell jar 14 and with a structure 30 sustaining the coil 16, which with an upper cover 32 defines an upper chamber

34 communicating through a window 36 with an air-water heat exchanger 38 in its turn connected with an external chamber 40 defined by an external metallic compartment 42, abutting too on the plane 24, and enclosing the whole air circuit surrounding the bell jar 14. A blower 44, actuated by a motor 46, intakes air from the external chamber 40, admitting it in the pressurizing chamber 21, through an opening 48. From here the air passes licking the bell jar 14 through a swirl generating nozzle 50, provided with deflecting and conveying blades 52, providing the air with a swirling movement, evidenced by arrows 54 (see specifically figure 2). Further to pass through the nozzle 50, the cooling air can pass through the separating gaps 56 between the single turns 18 of the coil 16, enhancing the turbulence which helps the heat removal from the walls of the quartz bell jar 14.

Said gaps 56 can be also provided with opening regulating iris diaphragms to effect the air flux through them and thus the wall temperature of the bell jar 14.

The susceptor 12 having shape of truncated pyramid with a polygonal basis (hexagonal in this examples), is provided with a plurality of faces 58 in which are cut pockets or indentations 60 housing wafers or slices 62 of material to be treated, such as the typical silicon wafers to be submitted to epitaxial growth. Said susceptor 12, brought by a support 64 is rotated by a shaft 66 passing through a suitable sealing support and actuated by a motor (not shown), said support being integral with a pushing support 68 abutting against the lower basis of the bell jar 14, to keep it pushed against a gasket 70, comprised between the bell jar basis and the lower plane 24 and against a sealing pierced plate 72, pushed by springs 74 abutting against supports 76, permitting to introduce through a pipe 78 and gases to be used in the epitaxial reactor, as for example, SiCl_4 , SiHCl_3 , H_2 and other gaseous components, such as aluminum and phosphor compounds, to assure the proper silicon doping.

The susceptor 12 temperature, during the reactor working is detected by at least one optical pyrometer 80, movable according to the arrows 82 and 84, surveying the susceptor 12 through the gaps 56 between the turns 18 of the coils 16, and connected through a cable 86 to a first processing center 88, as for example an analogic to digital converter (A/D) which through a cable 90 sends temperature data to a central processor 92 receiving through a multiple bus 94 all the directions and data for the managing of the whole epitaxial reactor and emitting the regulating signals, as for example a first signal through a line 96, to control the speed of the motor 46 actuating the blower 44, a second signal through a line 98 for an actuator 100

of a flux regulating valve 102 to regulate the cooling water flux in the air-water heat exchanger (38) and a third signal through a line 104 for the current control in single turns of the coil 16 according to a system hereinafter disclosed.

Alternatively, instead of a single movable pyrometer 80, can be used a plurality of optical pyrometers, suitably positioned in many suitably chosen surveying points and by turn connectable to the above mentioned first processing center 88 through one of many electronic switching circuits widely diffused and well-known in the present information processing art.

As already stated, it is possible to locally variate the current in specific turns of the coil 16, shunt connecting them to capacitors such as the capacitor 110, or to inductors. Such as the inductor 112, which can be variated by means the use of cores, such as the ferromagnetic core 114 introduced in or withdrawable from the same through an actuator 116, such as a motor acting on the racked rod 118 connecting to said ferromagnetic core 114. Said ferromagnetic core can be formed by a stack of laminations particularly thin and well insulated, suitable for the frequencies (1 kHz to 20 kHz) of the current energizing the inductor 16, or by cylindrical ceramic ferrite rod, having high magnetic permeability and standing high magnetic fields, of the kind used in transformers for voltage convertes controlled by semiconductor devices.

The racked rod 118, moved by the actuator 116, is also provided with a position transducer 120, having the duty to inform the central processor 92, through a line 122, about the position of the core 114 within the turns of the inductor 112.

The possibility for controlling locally the current in specifically turns of the coil 16 in order to control locally the electromagnetic field and thus the power induced in the susceptor 12, can be better understood by referring to figures 3, 4 and 5.

Reference is made to the simpler case in figure 3a. A coil 16 is fed by an alternating current generator, indicated by the numbered 126 and resonates at the frequency of the generator 126 by means of a shunt connected capacitor 128 duly shaped to produce such a resonance.

If same taps at indicated turns of the coil 16 are considered, said taps permit the coil 16 to work as an autotransformer and if some reactive loads are connected to said taps, it is possible to derivate a current between a pair of said taps.

Due to the fact that the reactive load is inductive or capacitive in nature, the current derived between said two taps is subtracted from or added to the current in the coil turns. According to the example depicted in the figure 3a, between the tap pair 132 and 134 can be connected some capacitors 110a, 110b, 110c etc..., in order to obtain

some selectable current increases between said tap pair. Owing to the very high current crossing said sometime water cooled capacitors, it is preferable that the connections to said capacitors are hand performed by means of proper connectors through the help of suitable tools used to move fastening screws or bolts.

In a like way between the tap pair 136 and 138 of the same coil 16 is connected a load inductor 112, provided with a short circuit conductor 140, consisting for example of a plate connectable by means of bolts between taps 142 of adjacent turns of said load inductor 112. The kind of the here above mentioned control can just hand connected and controlled and can produce just some preselected fixed regulations of the current in the coil 16. Moreover to perform said regulations, the power to the coil 16 must be disconnected, and as a consequence, the work and production of the reactor must be shut-down.

In order to have a continuous and automated regulation of a current, derived for example between the tap pair 136 and 138, the assembly in figure 3b is used. In this figure the inductance of the inductor 112, connected between the taps 136 and 138 is varied by moving a ferromagnetic core 114 in and out said inductor, said core being moved by an actuator 116 controlled through a line 104 by the central processor 92, receiving from a line 90 signals coming from an optical pyrometer 80, measuring the susceptor temperature and thus the local power density connected with the current in individual coil (16) turns, and from a line 122 position data produced by a transducer 120 referring about the core 114 position within the inductor 112. The above mentioned device, depicted both in figures 3b and 1, permitted to variate continuously, controllably and automatically the current derived between the taps 136 and 138 of the coil 16.

The further improvement of the reactive load circuit of the coil 16 depicted in figure 3c, consists in a combination of many capacitors 110a, 110b, 110c, connectable between the taps 136 and 138, possibly shunting the inductor 112 variable by means of the movable ferromagnetic core 114.

A switch or relay contact assembly 144a, 144b, 144c, ... and 146 permit the shunt connection of one or more capacitors and/or the variable inductor 112. What is obtained is a parallel resonant circuit which, by varying its constants (i.e. inductance and/or capacitance) resonates to frequencies higher or lower with respect to the generator 126 frequency giving the reactive circuit either inductive or capacitive features, respectively and permitting through the simple variation of the inductor 122, to continuously change the features of said circuit from capacitive to inductive and vice versa, permitting a particular versatility of the coil 16.

The specific working of said reactive circuit will be explained with reference to the diagrams of figures 4 and 5.

A further reactive circuit having two features variable between inductive and capacitive ones is that depicted in figure 3d. In said circuit there are some capacitors 110a, 110b, 110c.... shunt connectable each other and successively series connected with a variable inductor 112' provided with a movable core 114'. This reactive circuit is actually a series resonant circuit which, by varying its constants, can resonate at frequencies lower or higher with respect to the generator 126 frequency, giving the reactive circuit capacitive or inductive features, respectively. Some switches or relay contacts 144'b, 144'c, permit to shunt connect the capacitors 110'b, 110'c, in respect of the capacitors 110'a, while a further switch or relay contact 144'a short circuits, excluding them, all the capacitors 110'a, to 110'c, and a further switch or relay contact 146', short circuits, excluding it, the inductor 112'. This reactive circuit, formed by a series connected resonant circuit can work equivalently to the parallel resonant circuit, having however the drawback that near the resonance frequency the circuit could stand too high currents and further across the reactive members can develop such high voltages to suggest the provision, at least across the capacitors 110'a to 110'c of a voltage limiting member 150, such as a voltage dependent resistor (VDR) or varistor, to protect them against such overvoltages. For a full understanding of the working of the figure 3c circuit, which is the most preferred, reference is now made to figures 4 and 5, depicting impedance and phase angle, between voltage and current, diagrams, respectively, for different inductance and capacity combinations and diagrams for currents added to or subtracted from the coil 16 for different capacitors against a continuous inductance variation.

According to the diagrams A, a circuit having a 31.3 microhenries inductance and a 24 microfarads capacity resonating at the 5.75 kHz frequency, behaves at the 10 kHz frequency as an almost pure capacitor, having of course lesser capacity. According to the diagrams B, a circuit having a 15.8 microhenries inductance and a 16 microfarads capacity, resonating exactly at 10 kHz, behaves as a pure resistor, while according to the diagrams C a circuit having a 8.07 microhenries inductance and 16 microfarads capacity, resonating at 14 kHz, behaves at the 10 kHz frequency, as an almost pure inductor, having of course lesser inductance. Figure 5 clearly depicts how, by varying the inductor 112 for a given capacity of the capacitors 110, it is possible to go from a current subtracted from the turns of the coil 16 to a current added or introduced in said turns. For example the first dia-

gram marked out for a 32 microfarads capacity, depicted that with a 6 microhenries inductance the reactive circuit subtracts a 30 amperes current from coil 16 turns on which a 50 volts voltage is formed (this, of course, at 10 kHz frequency), while with a 30 microhenries inductance adds to said turns an about 70 amperes current with the current being substantially zeroed for a 8 microhenries inductance at which there is the 10 kHz resonance.

With a 24 microfarads capacity and a 6 microhenries inductance, the circuit subtracts a 55 amperes current from and with a 30 microhenries inductance introduces a current of about 45 amperes in the coil 16, being said current substantially zeroed at the resonance condition at 10 kHz provided by an about 10.5 microhenries inductance. The remaining diagrams can be understood in a similar way, remarking that by lowering the capacity with the same inductance the current subtracted from the coil 16 is increased while the current admitted to the coil 16 is decreased. Reference is now made to figures 6 and 7 in which is depicted a first assembly to reduce the dispersion of the magnetic field produced by the coil 16, outside the same. Said dispersion reduction is obtained by providing some angularly shaped blocks 160, 160a, 160b, ... and 170, 170a, 170b,... of ferromagnetic material near the upper and the lower edge of the coil 16, respectively. Said blocks, made for example of very thin silicon-steel laminations, to take into account the working frequency, guide the ferromagnetic field reshaping it from the highly dispersed form indicated by the symbol H_1 to the more concentrated and near the coil 16 form indicated by the symbol H_2 . It is evident that outside the coil 16 the field H_2 reduces itself faster than the field H_1 , strongly reducing the heating of metallic components which can be immersed in said field, however the lesser heating of said metallic components finds a negative counterbalance in the heating of the blocks 160-170 which, because of the high power, can require a water cooling thereof.

The last mentioned drawback can be very reduced replacing the lamination blocks 160-170, depicted to figures 6 and 7, with blocks 180-190, depicted in figures 8 and 9 of magnetic material, electrically little conductive or insulating, such as the well known ceramic ferrites which, moreover, have very little power losses at the working frequencies. Further considering figures 8 and 9, it is seen that blocks 180, 180a, 180g, surround the top edge of the coil 16 and the blocks 190, 190a, 190d, etc... surround the bottom edge of the same coil 16, permitting the shaping of a magnetic field H_3 between the inside of the coil 16 and external paths formed by said blocks 180, 180a, 180g, and 190, 190a-190g, and by columns 200, 200a-200g connecting the above mentioned blocks in order to

reduce at the minimum the magnetic field dispersion outside the coil 16.

In order to assure specific heating profiles to the indentations or pockets 60, having purposes to accomodate wafers or slices of the material to be treated, on the faces 58 of the susceptor 12, can be used specific shapes of the internal faces 59 of the susceptor 12, aligned with said pockets 60, as depicted in figures 10, 11 and 12. Particularly in figure 10 behind the pocket 60 is provided a depression 210, having shape of a circular trench, surrounding a planar area 212 at the same level of the remaining face 59. In figure 11, behind the pocket 60, is provided a bevelled depression 214 having shape of a circular corona, gradually rising from the external to the internal circumference, to reach a planar area 216 at the same level of the face 59. In figure 12, behind the pocket 60, is provided a continuous relief, reminding a conical surface, having top in a vertex 218 substantially aligned with the center of the pocket 60.

Everyone of these indentation or relieves depicted in figures 10, 11 and 12 produces in the pockets 60 temperature profiles obvious to people skilled in the art, having in mine that to a lesser susceptor thickness corresponds higher temperature in the susceptor and thus in the wafer accomodated in said pockets 60.

A further measure, to be taken is to provide the lateral corners of the susceptor 12 with bevellings larger outside than inside in order to maintain constant or reduce locally the susceptor thickness and thus maintain constant or increase locally the current density therein. In the present specification have been depicted as an example, some improvements to coils and susceptor of epitaxial reactors permitting them a particularly proper working required for treating wafers accomodated in the pockets 60 of the susceptors 12.

Obviously, a person skilled in the art will be able to find out aproaches and measures wholly o partially equivalent to those depicted in the present specification and it is here intended to cover all said equivalent measures and approaches falling in the scope of the present invention ad defined by the following claims.

Claims

1. In a reactor for the deposition of epitaxial layers from a vapor phase on crystalline substrates consisting in a rotating susceptor (12), heated by means of currents induced by turns of a coil (16), housed in a bell jar (14) of insulating and optically transparent material, such as quartz, surrounded by a reflector having the purpose to reflect to said susceptor the heat irradiated therefrom during the

working, improvements to said coil (16) characterized by using as a reflector the internal side optically finished of turns (18), forming said coil (16), said turns being provided by hollow conductors, travelled by a cooling liquid, distances between each other in order to have minimal continuity solutions of the reflector formed by said turns and fixed in a mechanically steady configuration or shape, local variations in the magnetic field inside the coil (16), necessitated by asked local power variations in said susceptor, being provided by means subtracting or adding current in a reactive way from or to said preselected turns (18) of the coil (16) corresponding to susceptor (12) regions in which said power variations are asked.

2. In a reactor, according to claim 1, the improvement characterized by the use of a coil (16) whose turns (18) are provided by ring shaped conductors, lying on planes substantially perpendicular to the susceptor (12) axis in order to induce therein electrical currents perpendicular to said axis to avoid heating pulsations connected with a perpendicularity lack of said currents in respect of said susceptor axis and with the rotation of the same susceptor.

3. In a reactor, according to claims 1 and 2, the improvement characterized by using, to cool said bell jar (14), blowed air, coming from a blower (44) guided by a nozzle and swirl generator (50) to flow between said bell jar (14) and said coil (16) thus coming out from about said bell jar (14) to be cooled by heat exchanged means (38) to come back to said blower (44).

4. In a reactor, according to claim 3, the improvement characterized in that the air coming out said blower (44) comes first in a pressurizing chamber (21) and therefrom passes between the bell jar (14) and the coil (16) both through said nozzle and swirler (50) and through suplementar taps consisting of gaps (56) between the turns (18) of said coil (16).

5. In a reactor, according to claim 1, the improvement characterized in that the means to subtract reactively current from turns (18) of said coil (16) are provided by inductors (112) connected between said turns (18) and the means to add reactively currents to said turns (18) are provided by capacitors (110) connected between said turns (18).

6. in a reactor according to claim 5, the improvement characterized in that said inductors (112) are variable.

7. In a reactor, according to claim 6, the improvements characterized in that anyone of said inductors (112) is variable by connecting its taps (142) to a short circuit conductor or bridge (140).

8. In a reactor according to claim 6, the improvement characterized in that anyone of said inductors (112) is variable by means of a ferromagnetic core (114) therein movable.

9. In a reactor, according to claim 5, the improvement characterized in that anyone of said capacitors (110) is variable.

10. In a reactor, according to claim 9, the improvement characterized in that anyone of said capacitors (110) is variable by increment, shunt connecting a selectable number of capacitor members.

11. In a reactor, according to claim 5, the improvement characterized by at least one inductor (112) and capacitor (110) combination.

12. In a reactor, according to claim 11, the improvement characterized in that said at least one inductor (112) and capacitor (110) combination is a parallel combination thereof with a capacitor (110) variable by increments and an inductor (112) variable by means of a ferromagnetic movable core (114).

13. In a reactor according to a claim 11, the improvement characterized in that said at least one inductor (112') and capacitor (110') combination is a series combination thereof with a capacitor (110') variable by increments and an inductor (112') variable by means of a ferromagnetic movable core (114').

14. In a reactor, according to claim 13, the improvement characterized in that across said capacitors (110') is connected a voltage limiting number (150) to limit possible overvoltages which could be formed in said capacitors (110') near resonance conditions.

15. In a reactor, according to claim 1, the improvement characterized in that said coil (16) is provided with ferromagnetic blocks (160, 170, 180, 190) having the purpose of guiding and limiting the magnetic field outside the coil (16).

16. In a reactor, according to claim 15, the improvement characterized in that said blocks (160, 170, 180, 190) have an angular shape and are provided around the top and the bottom edge of the said coil (16), respectively.

17. In a reactor according to claim 16, the improvement characterized in that said blocks (160, 170, 180, 190) consist of ferromagnetic lamination stacks.

18. In a reactor according to claim 16, the improvement characterized in that said blocks (160, 170, 180, 190) consist of ceramic ferrite.

19. In a reactor, according to claim 15, the improvement characterized in that said ferromagnetic blocks (160, 170, 180, 190) are connected by an external ferromagnetic shell around the outside of said coil (16).

20. In a reactor, according to claim 19, the improvement characterized in that said blocks (160, 170, 180, 190) and said shell consist of ceramic ferrite.

21. In a reactor, according to claim 18, the improvement characterized in that said ferrite blocks (160, 170, 180, 190) are connected by ferrite columns (200) outside said ferrite coil (16).

22. In a reactor according to claim 1, the further improvement in said susceptor (12), consisting in a conducting shell have shape of a truncated pyramid with a regular polygonal basis, having an external (58) and an internal (59) surface, the further improvement characterized in that the internal surface (59) of said shell is provided with depressions or relieves aligned and substantially coextensive and pockets or indentations (60) on said external surface (58) accomodating wafers of slices (62) of material to be treated.

23. In a reactor, according to claim 22, the improvement characterized in that thickness variations of the susceptor (12) compensate for induced power variations connected with the pyramidal shape of said susceptor (12).

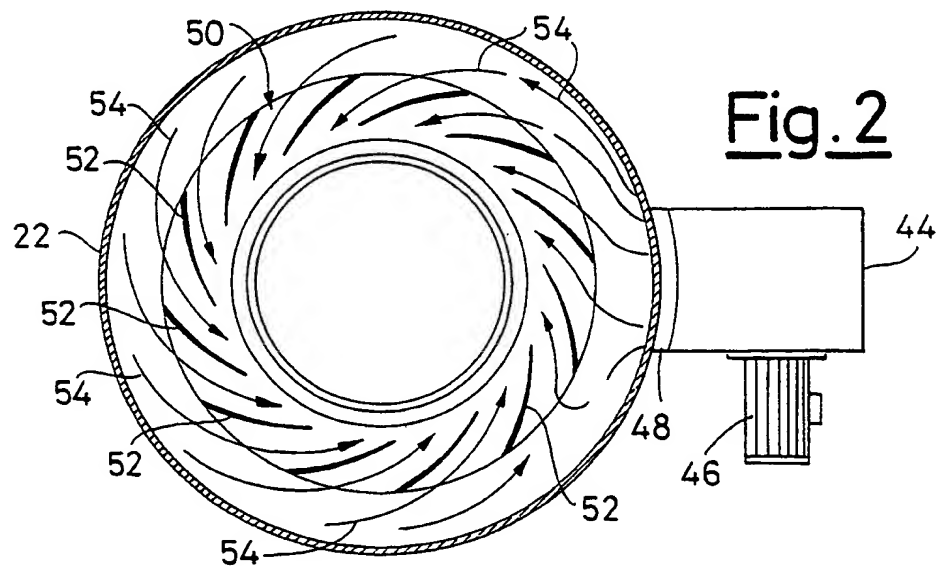
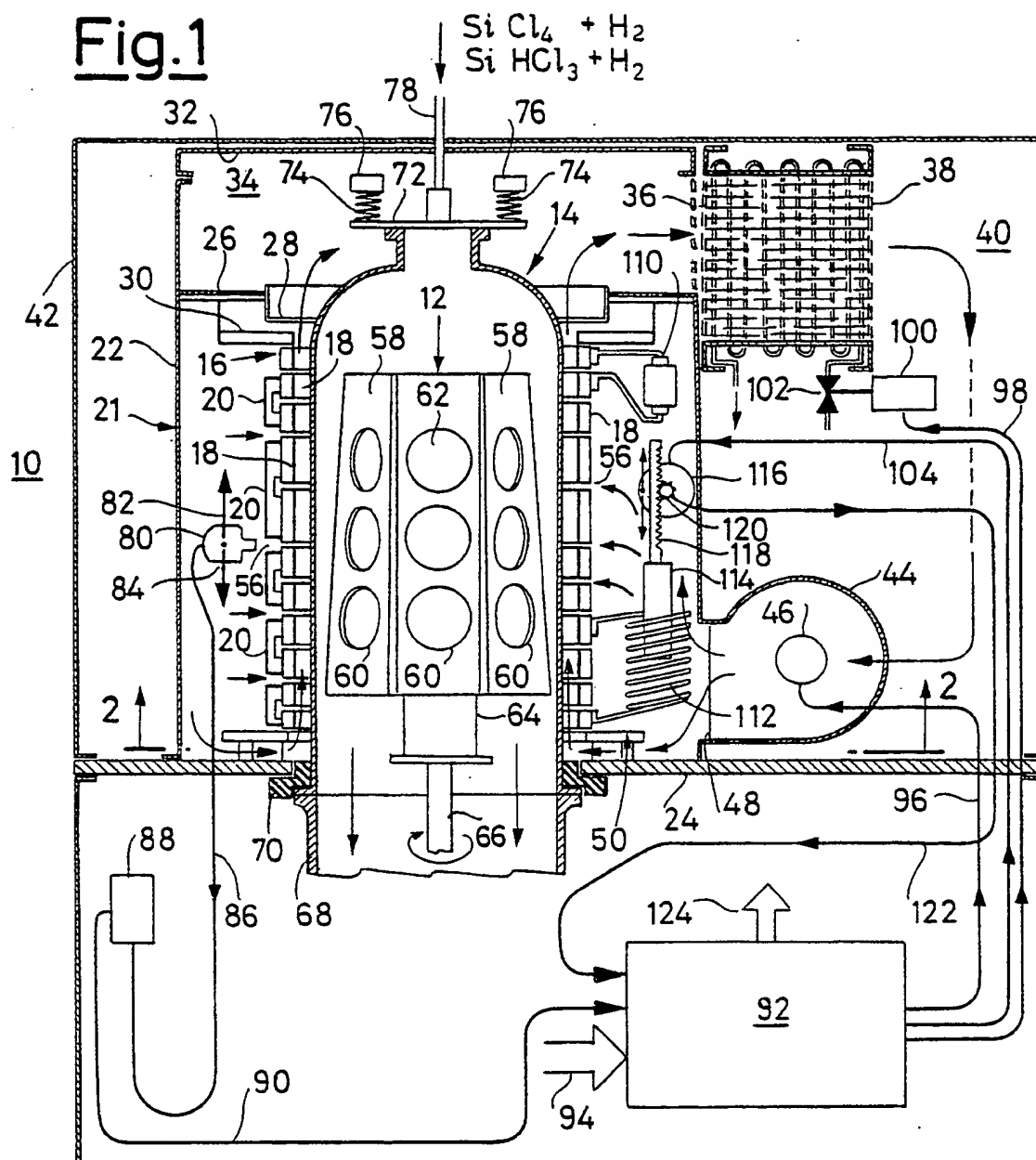
24. In a reactor, according to claims 22 and 23 the improvement characterized in that said depressions aligned with said pockets (60) are planar depressions having shape of circular trenches (210), surrounding a central area (212) substantially at the same level of said internal surface (59).

25. In a reactor according to claims 22 and 23, the improvement characterized in that said depressions are circular trenches (214) bevelled starting from a central area (216) substantially at the same level of said internal surface (59).

26. in a reactor, according to claims 22 and 23, the improvement characterized in that said relieves are generally conical surfaces, on the internal face (59) of said susceptor (12) having vertices (248) substantially aligned with the centers of said pockets (60).

27. In a reactor, according to claims 22-26, the improvement characterized in that the lateral corners of the susceptor (12) are provided with bevelings well larger outside than inside in order to maintain or reduce locally the susceptor (12) thickness and thus maintain or increase locally the current density in the same.

28. In a reactor according to claim 1 the improvements in the coil (16) according to claims 1-21 and in the susceptor (12) according to claim 22-27.

Fig.1

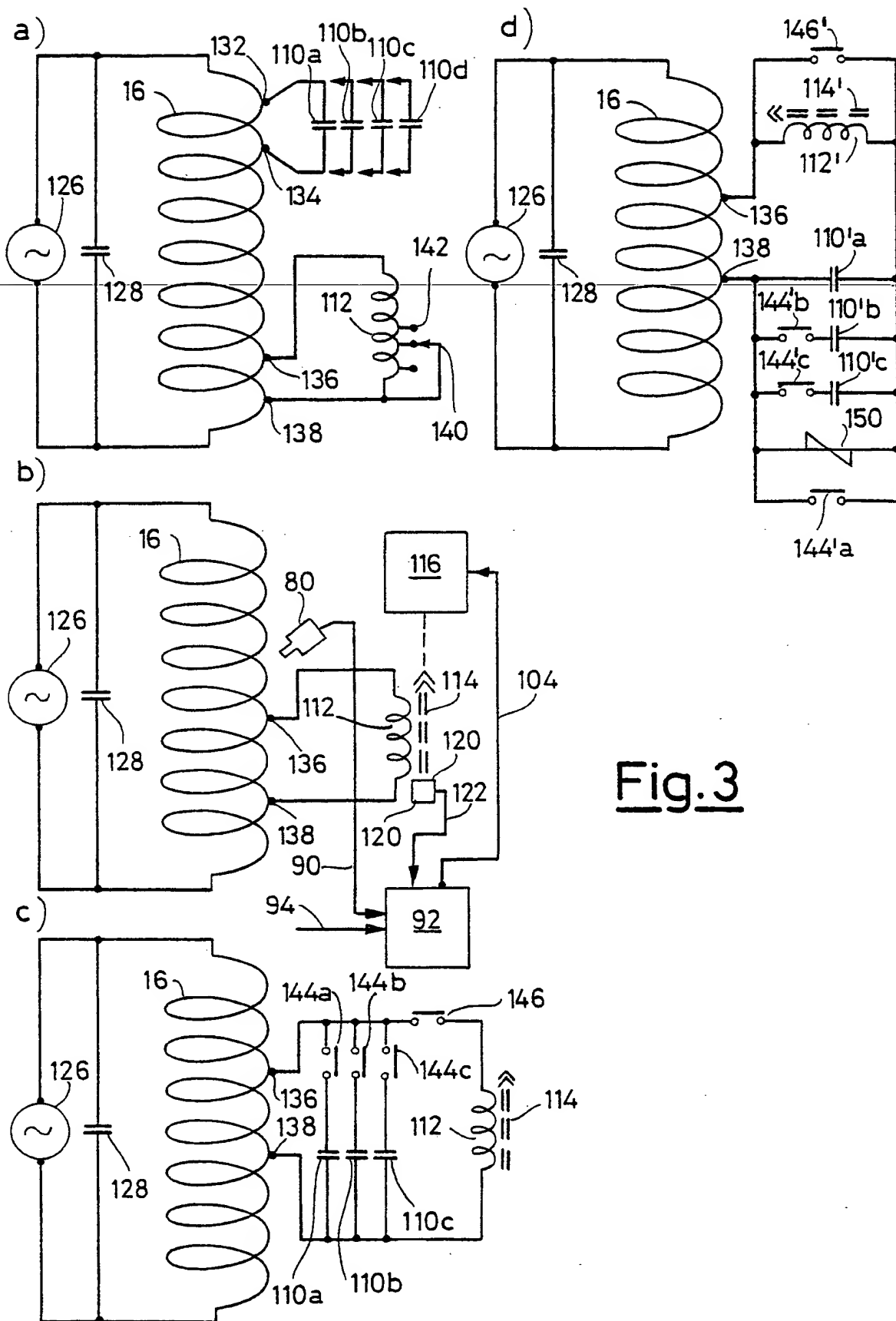


Fig.3

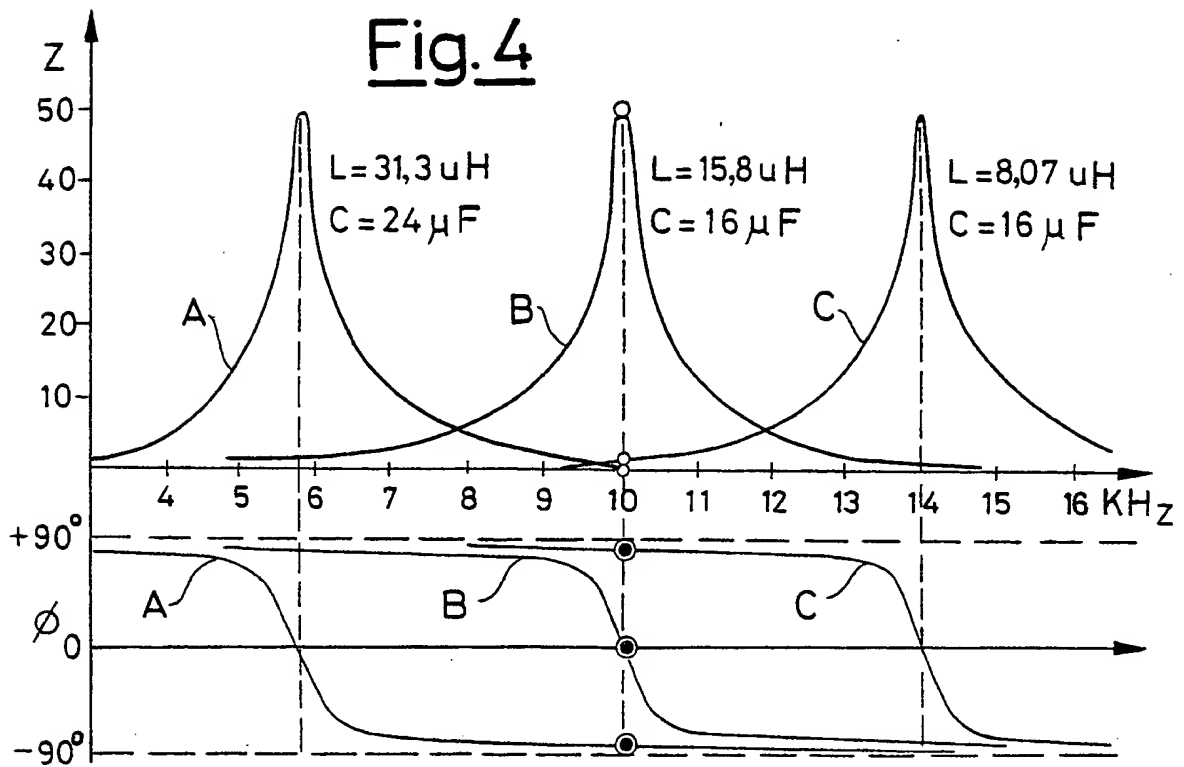
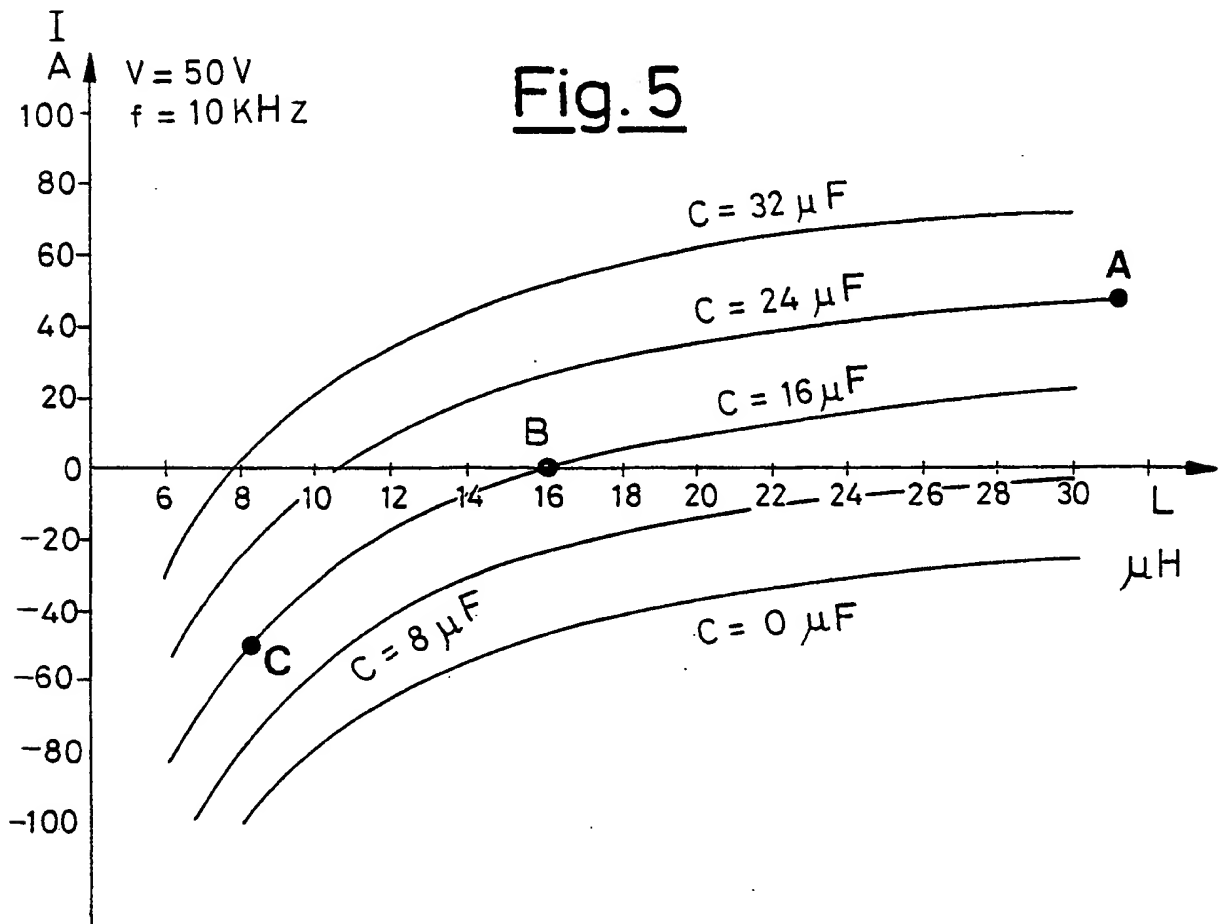
Fig. 4Fig. 5

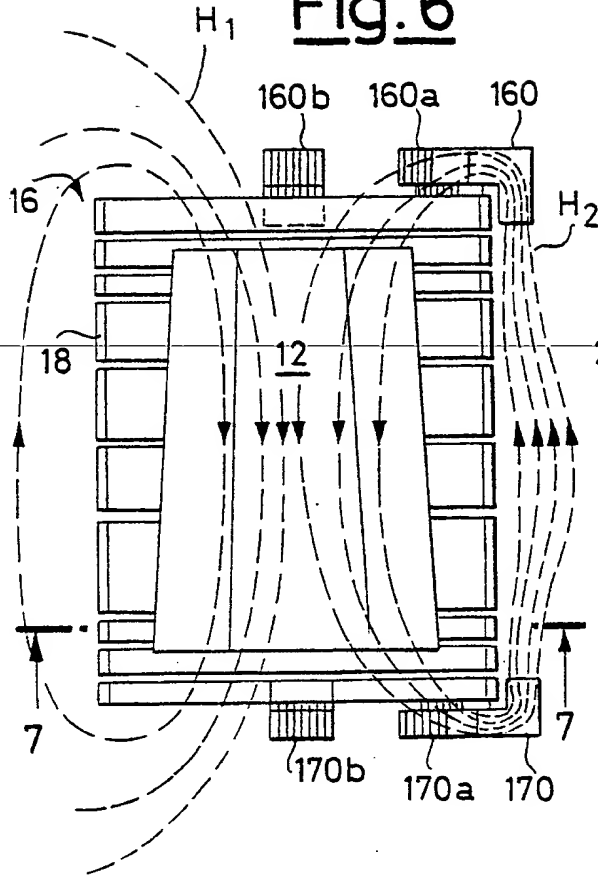
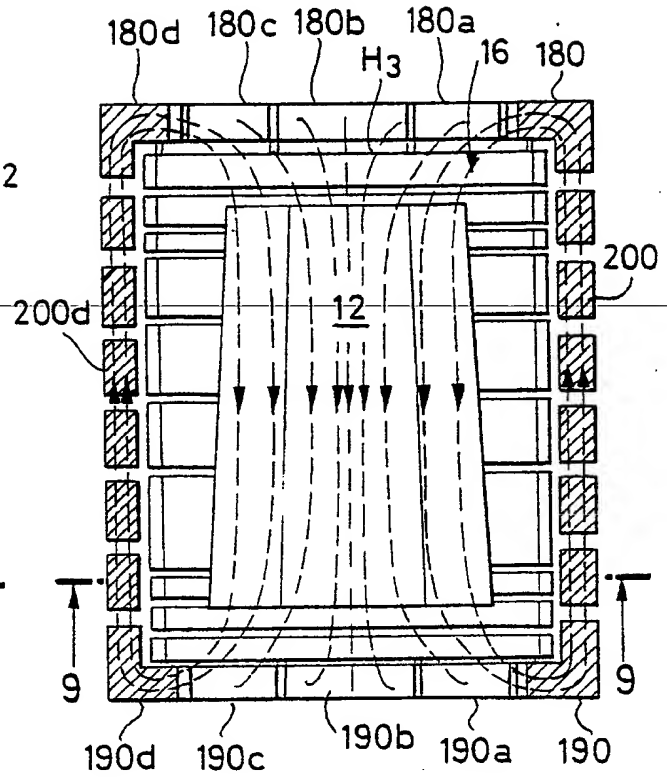
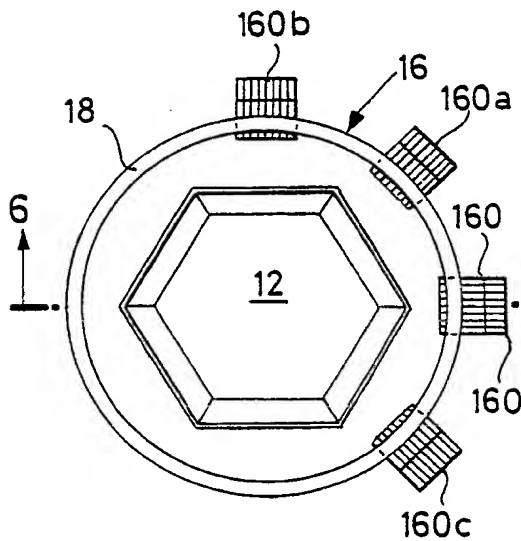
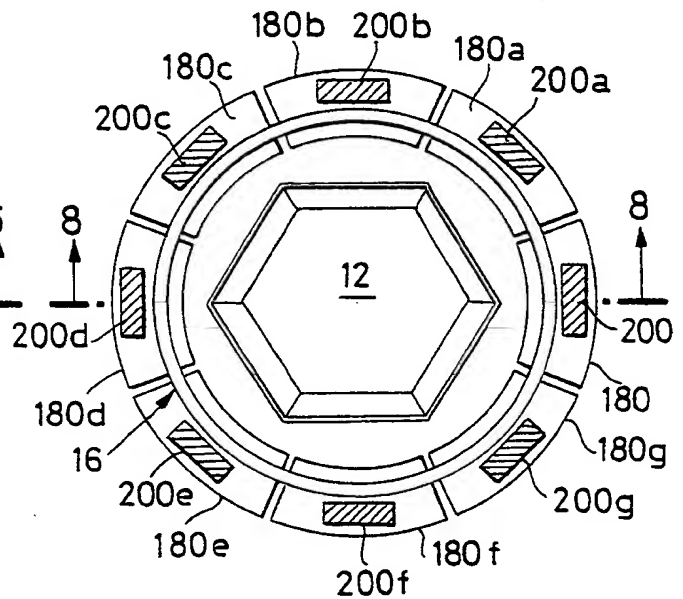
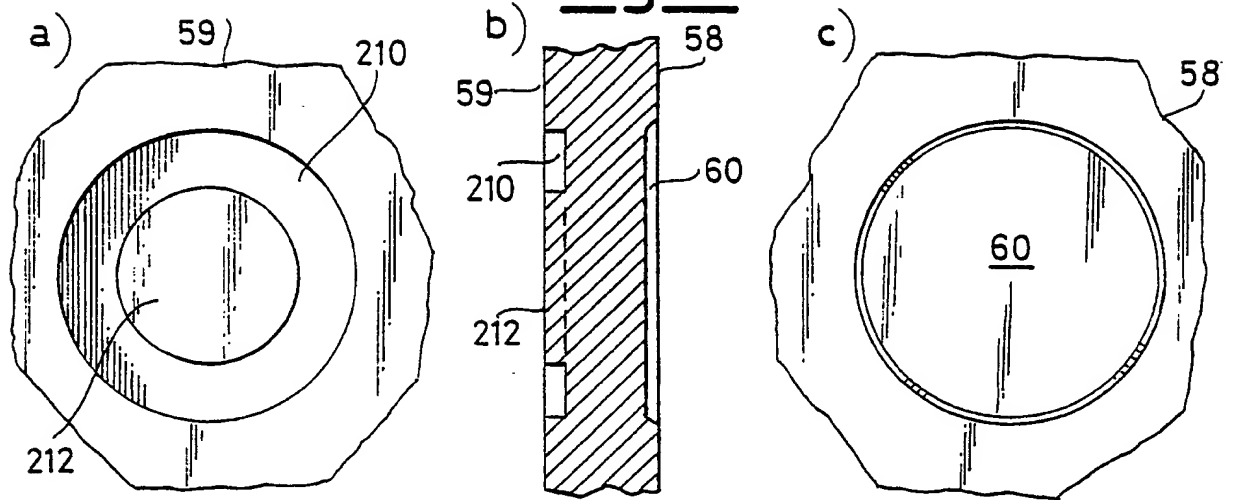
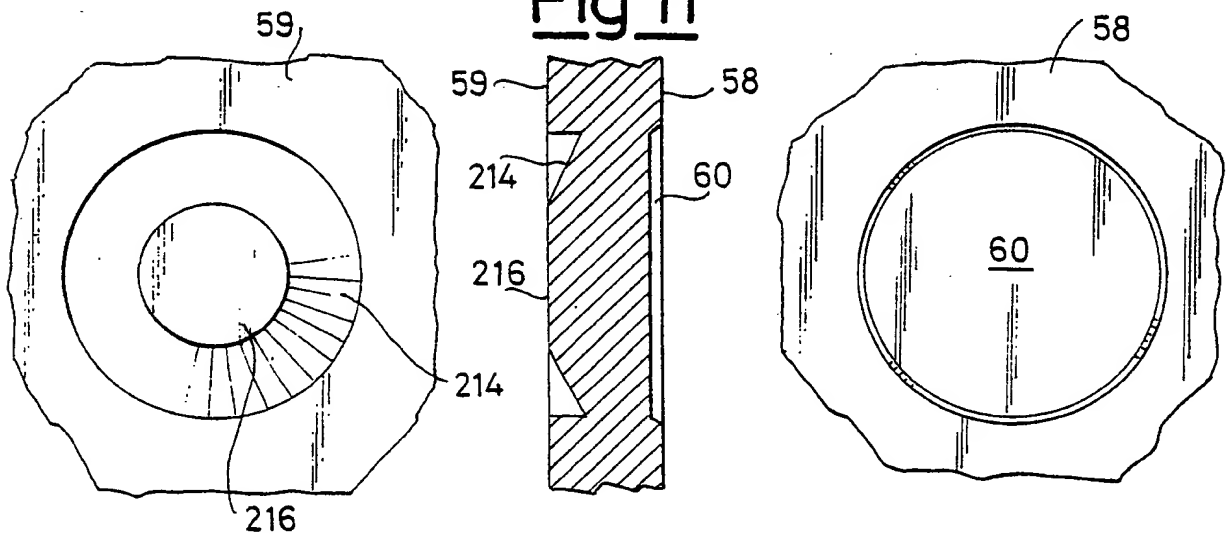
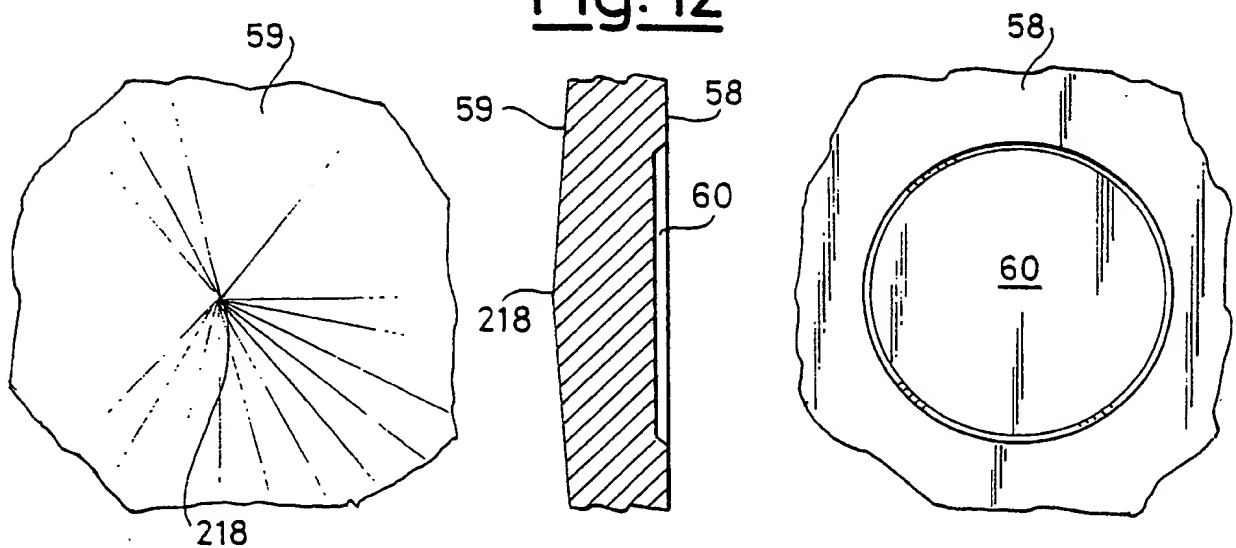
Fig. 6**Fig. 8****Fig. 7****Fig. 9**

Fig. 10**Fig. 11****Fig. 12**

(19)



Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) Publication number:

**0 293 021
A3**

(12)

EUROPEAN PATENT APPLICATION

(21) Application number: 88200614.1

(51) Int. Cl.⁵: C30B 25/10

(22) Date of filing: 31.03.88

(30) Priority: 24.04.87 IT 2025587

(43) Date of publication of application:
30.11.88 Bulletin 88/48(94) Designated Contracting States:
CH DE FR GB LI NL(88) Date of deferred publication of the search report:
16.05.90 Bulletin 90/20

(71) Applicant: **LPE SPA**
Via Stella Rosa (Head Office)
I-20021 Ospiate di Bollate Milano(IT)

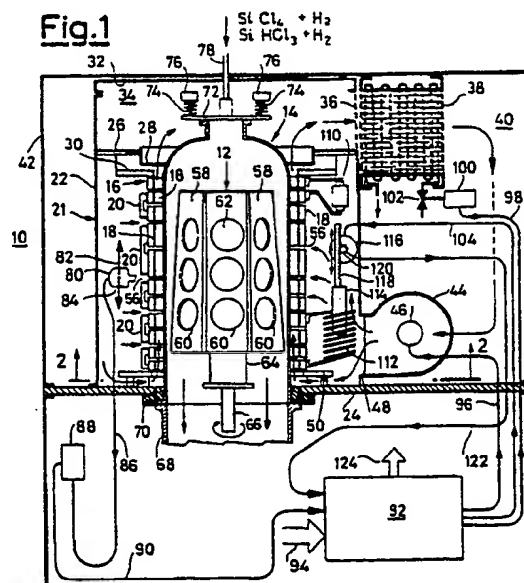
(72) Inventor: **Pozzetti, Vittorio**
Via Volturmo 80
Brugherio (Milano)(IT)
Inventor: **Preti, Franco**
Via S. Benigno 4
Milano(IT)
Inventor: **Poggi, Piergiovanni**
Via delle Scuole 24
Lugano Cassarate(CH)

(74) Representative: **Michelotti, Giuliano et al**
c/o SAIC BREVETTI S.r.l. Viale Bianca Maria
15
I-20122 Milano(IT)

(54) Induction heating system for an epitaxial reactor.

(57) Is described a reactor for chemical vapor deposition of epitaxial layers on crystal substrates, using a medium frequency induction heating system, the power for said heating being provided by a multi-turn coil (16), inducing electrical currents in a susceptor (12) of electrically conductive material, as graphite, said heating being controllable through fine local and readily automaticable current regulators in single turns (18) of said coil (16) and through properly shaping the walls (59) of said susceptor (12) in order to control temperature gradients therein.

Fig.1



EP 0 293 021 A3



European Patent
Office

EUROPEAN SEARCH REPORT

Application Number

EP 88 20 0614

| DOCUMENTS CONSIDERED TO BE RELEVANT | | | |
|---|---|--|---|
| Category | Citation of document with indication, where appropriate, of relevant passages | Relevant to claim | CLASSIFICATION OF THE APPLICATION (Int. Cl. 4) |
| A | FR-A-2 567 921 (LPE S.p.A.) * Page 4, lines 13-35; page 5, lines 13-17; page 10, lines 5-15; claim 1 * | 1,22 | C 30 B 25/10 |
| A | US-A-3 645 230 (HUGLE et al.) * Column 3, line 74 - column 4, line 33 * | 1 | |
| A | EP-A-0 147 967 (APPLIED MATERIALS INC.) * Page 8, line 28 - page 10, line 5; page 17, lines 17-31; page 32, lines 4-18 * & US-A-4 579 080 (Cat. D) | 1,22,23 | |
| A | US-A-3 964 430 (PURMAL) * Column 2, line 51 - column 3, line 37 * | 1,3 | |
| A | AU-A- 39 328 (UNISEARCH LTD) * Page 6, lines 9-17; figure 2 * | 1 | |
| A | IBM TECHNICAL DISCLOSURE BULLETIN, vol. 23, no. 3, August 1980, pages 1061-1062, New York, US; J.P. BRONCHARD et al.: "Wafer temperature measurement in epitaxial and pyrolytic deposition equipment" | | TECHNICAL FIELDS SEARCHED (Int. Cl.4) C 23 C C 30 B |
| The present search report has been drawn up for all claims | | | |
| Place of search THE HAGUE | | Date of completion of the search 22-01-1990 | Examiner COOK S.D. |
| CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document | | | |